THE BASCULE DRAW SPAN
OF THE
ARLINGTON MEMORIAL BRIDGE

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SUMMARY

The object of this thesis is not to discuss the whole of the Arlington Memorial Bridge, but rather to give some facts concerning the bridge in general and discuss in more detail the construction, erection, and operation of the bascule draw span.

The bridge consists of ~~none~~ nine main spans, the middle one of which is a steel draw span, and the four flanking on each side are mason~~a~~ry. The mason~~a~~ry arches are of reinforced concrete construction, with all the visible surfaces faced with granite. In order to keep the symmetry of design, as the bridge was designed with the specific objective to make it a work of art, the bascule lift span was used. The design was carried out in the lift span by making its sides of fascia of pressed ornamental molybdenum steel to simulate the construction of the mason~~a~~ry spans. In the actual construction of the bridge, several problems were met. It was necessary to establish a contractors' yard on the Arlington side of the river where materials were received and subsequently transported to the site of the bascule by means of barges. The various pieces were lifted into position by means of a derrick on the bascule abutments and on the boats.

In the construction of the counterweights it was necessary to use a large quantity of punchings to give the necessary weight. As the necessary amount of scrap steel which is commonly used could not be obtained a cargo of Swedish ore was imported and used. One leaf of the bascule was constructed at a time so that navigation could proceed. After the copper-molybdenum had been placed on the masking trusses of the Washington leaf which was completed first, the leaf was raised and found to balance excellently.

The entire draw span was built at a cost of a little over $900,000. It can easily be seen from the fact that the ornamentation for the draw cost $400,000, almost one-half of the total, that great pains were taken by the Special Commission in charge to improve the appearance of the bridge.

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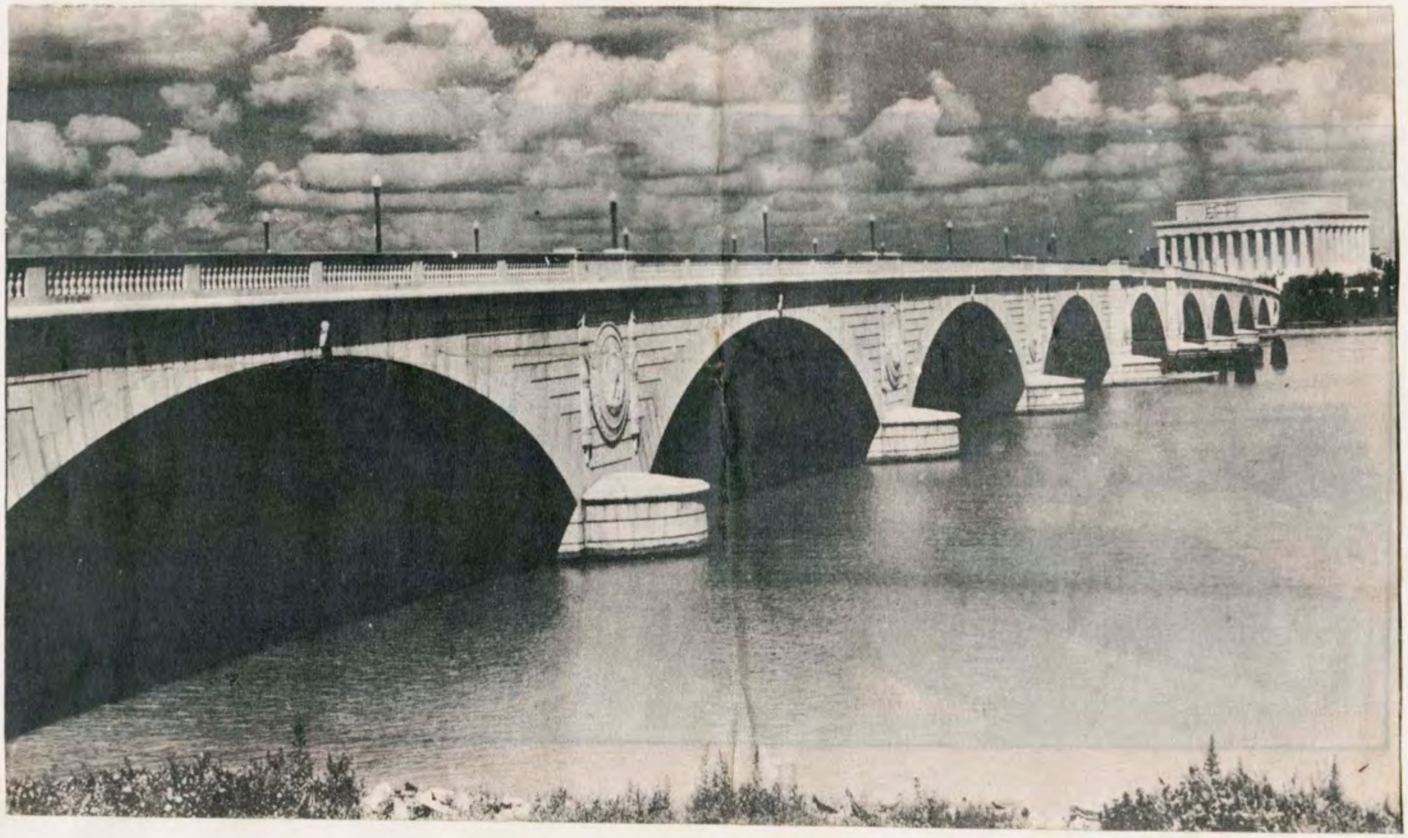
THE BASCULE DRAW SPAN OF THE ARLINGTON MEMORIAL BRIDGE

The Arlington Memorial Bridge spans the Potomac River from a point on the north bank about 100 yards from the south west corner of the Lincoln Memorial to a point on the south bank approximately one fourth of a mile from the Arlington Cemetery. The bridge, with the exception of the bascule draw span, is of reenforced concrete construction, with all the visible surfaces, except the soffits of the arches, faced with brush-hammered granite. The granite on the lower portions of the arches is from Stone Mountain Quarry in Georgia. The remainder of the granite was taken from the Mount Airy Quarry in North Carolina.

The bridge has an overall ~~legnth~~ length of 2,163 feet and a clear width between the balustrades of 90 feet. The width of the roadway between the curbs is 60 feet, and the width of each of the two sidewalks is 15 feet.

The design was governed largely by architectural considerations. In appearance it is a nine-span arch bridge, but it really consists of the eight main, concrete barrel arches of 166 to 180 foot spans and the 216 foot span bascule in the center which is faced with ornamental metal-work to harmonize with the brush hammered granite surfaces of the concrete arches. The substructure of the bridge consists of four abutments, one at each shore line and one at each end of the bascule span, and six piers. The piers are founded on solid rock which was found at a depth of from 35 to 45 feet below the surface of the river.

The total cost of the bridge was $7,250,000.00. An unusual feature of this cost is the fact the granite, including the granite



carving and the ornamentation of the draw span made up almost one-half of the total cost. The structure was built within the cost as originally estimated and approved.

The bridge was built by the Arlington Memorial Bridge Commission which had charge of the entire project. This commission was headed by Colonel U. S. Grant 3rd who acted as the executive officer, and John L. Nagle, the designing engineer. The Commission had for its specific objective the designing and construction of a bridge that would be a work of art. Since the bridge crosses the Potomac between the Lincoln Memorial and the Arlington National Cemetary it was paramount that it should be a structure of great beauty. Therefore, to carry out the symmetry of the chosen design the bascule lift span was used. This type was the most logical choice because the lift span could be covered with an ornamental iron frescia to present an appearance in keeping with that of the other eight granite faced concrete arches.

DESIGN OF THE BASCULE

The movable bascule draw span is one of the largest and heaviest bascules in the world. Each of the two 108 foot leaves and its concrete counterweight weigh 3,800 tons. Design, fabrication, and erection consequently involved difficult problems.

Each leaf of the bascule includes two bascule trusses mounted on a main trunnion resting in bearings on either side of the truss. The bearings are carried on vertical trunnion posts that transfer the load directly to the abutments. The counterweight under the floor hangs as a pendant from counterweight trunnions at the rear end of each bascule

truss, the arrangements being made in such a manner that the counterweight moves parallel to itself as the leaf rotates upon the main trunnions. At the center of the span the two leaves are locked together by a detail design so as to transmit shear and to maintain equal deflection for both leaves under all conditions of loading.

THE CONSTRUCTION AND ERECTION OF THE BASCULE

The approaches to the bascule were not complete when its erection was started, so that it was necessary that all materials be delivered by water. A contractor's yard was established and materials were received in the government reservation on the Arlington side of the river. A derrick car and crane in the yard ~~transfered~~ transferred the materials to the barges, on one of which an A-frame derrick was installed. From the yard to the site was one-third of a mile, and a tugboat was used to move the floating equipment between the two places. At the bascule site a thirty ton steel stiff-legged derrick was installed on each abutment, and materials were placed by these and by the derricks on the boats.

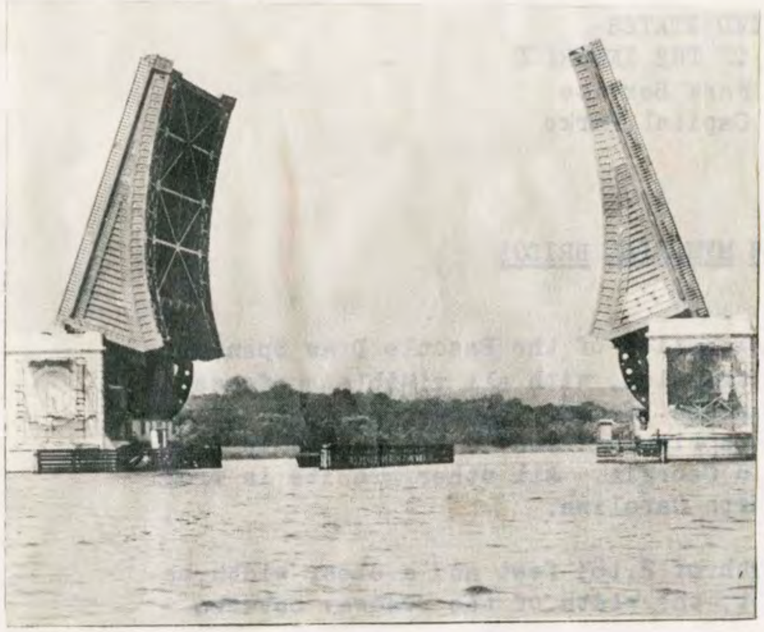
As the first step in the construction, the grillages under the trunnion posts and the trunnion bearings resting on the posts were set with extreme care. Before grouting, the grillages were leveled by set screws. Dowels of one and one-quarter inches were used for locating and adjusting, and dummy trunnions with a taut wire through their axes were utilized in aligning the trunnion bearings before planing and inserting the necessary shims. The distance between trunnion axes on

opposite abutments was carefully measured to insure proper matching of the leaves at the center of the channel. Machinery supports were also placed with great care. The trunnion posts were among the heaviest single pieces that had to be lifted, each section weighing 22 tons. After these and the bearings were placed, the rear portions of the main trusses and the heavy counterweight truss suspended between them were built. The heaviest single lift in the bridge weighed $31\frac{1}{8}$ tons and was composed of an assembley of the two main truss members and the gusset plates connecting them at the trunnion, the trunnion pin and the collars.

The first step in the construction of the counterweight was the placing of steel falsework, resting on the pit floor, to carry the mass of the counterweight, dimensions of which were 16 x 25 x 62 feet. Three inch planking in the falsework beams served as the bottom forms. The timber side forms were built in sections at the Arlington yard ready for assembley at the site. The volume ~~volumn~~ of each counterweight is 689 cubic yards. The weight per cubic foot required for the Washington leaf was 265 pounds and for the Virginia leaf was 255 pounds. The extra weight of the Washington leaf counterweight was caused by the center locking device. To secure the required unit weights punchings were specified to be used in the concrete mixture for the counterweight. The most satisfactory forms of steel scrap to be used for punchings as concrete ingredients are structural shop punchings. However, the counterweights on this bridge would have required about 3,000 gross tons of punchings. This amount was much to large to be accumulated within the specified time from the available sources. To solve this problem an effort was

made to find a material of a high specific gravity as a substitute for the structural steel scraps. The first material considered was "heating furnace cinder" (lumps of Fe_3O_4 obtained from heating furnaces). Then copper slag and various ores were tried. Some of these while having the high specific gravity proved to be to easily crumbled and thus unfit. Chilean ore was found to be suitable but unfortunately it was not available in sufficient quantities. The solution was to use Swedish ore which has the required physical characteristics an a specific gravity of 4.94. The entire cargo of a ship from Sweden which carried 2,400 gross tons was secured and brought by rail, making up a train of 59 carloads, to the Arlington yard. There it was run through a crusher to break up the large lumps, and then transported to the concreting plant on the bascule abutments.

Compression tests of concrete specimens which contained the Swedish ore showed that the strength was entirely satisfactory and so the materials were proportioned so as to get the desired unit weights and the concrete for the counterweights was mixed. The amounts of the ingredients in the concrete as mixed were 2200 barrels of cement, 125 tons of sand, 91 gross tons of fine Swedish ore, 1490 tons of coarse Swedish ore, and 1136 gross tons of punchings. About 146 tons of water were retained in the mixture. Exclusive of the concrete reinforcement rods, the total mixture in the counterweights ~~weighs~~ weighed (Keep same tense throughout P.!) 4787 tons. All materials were necessarily proportioned by weight. When the concrete was placed it was attempted at first to use a compacting machine, but this was found to be impractical because of the large amount of reinforcing steel.



The construction of the bascule was carried out by erecting on leaf at a time, in order that the concrete floor slab could be placed with the leaf closed. To protect navigation a fender 8 feet wide and 143 feet long was built around the abutments, when these fenders and the Washington counterweight were finished, navigation was restricted to the south half of the channel. Then the main trusses, masking trusses and all the bracing for the Washington leaf were erected by the derrick-boats. In this part of the work the heaviest single load lifted was the 26 ton end floor beam over the center of the channel. When all but the bottom chord splices of the trusses had been riveted, forms for the roadway and sidewalks floor slabs were put in place and the concrete was poured.

Before opening the leaf it was necessary to put on the copper-molybdenum on the masking trusses and to place and adjust the cast aluminum balustrades on the deck. The installation of the machinery and power line went along with the other work. When the finished leaf was raised it was found to balance perfectly.

The construction of the Virginia leaf was carried on in the same manner as the Washington one. Navigation now was confined to the north half of the channel.

OPERATION OF THE BASCULE

Each leaf of the bascule is operated by two motors directly connected to a herringbone-gear speed reducer. This gear has an ~~equal-~~
equali-

~~i~~zing device which enables it to deliver one-half of the total driving torque to each of the two main operating pinions, meshing with rack segments which are attached to the bascule trusses. Each operating motor is provided with a motor-mounted solenoid service brake. Then on each side of the shaft of the speed-reducer there is another brake, making a total of four in all. These auxiliary ~~auxilary~~ brakes can be used one at a time and they have sufficient braking power to hold the leaf fully open against a wind pressure of 15 pounds per square foot.

The power service at the bridge is in the form of alternating current. This is 3 phase, 60 cycle, 4000 volts. A 4000 volt, 300 H. P. motor is connected to two 100 Kw., 600 volt direct current generators, which supply current to the operating motors. They are set up so operating motors of either leaf can be supplied with power from either generator. The speed of the leaf varies directly with the voltage, so it is possible to get an extremely slow speed for seating the bascule leaves. In case that the regular power line supply should fail, a gaso- ~~gas-~~ ~~o~~line engine-driven generator has been provided.

CONTRACTS

The general contract for all the work on the bascule span was taken by the Phoenix Bridge Company of Phoenixville, Pa. They were able to erect the bascule at a total cost of $900,000 exclusive of the piers. $400,000 of this represents the cost of ornamentation necessary to keep the same appearance throughout the entire length of the bridge.

The Hunkin-Conkey Construction Company had the subcontract for the stone masonary work and concrete backing for abutments as well as for the concrete for houses and floor slabs.

The machinery for the job was contracted for by the Francis Machine Company of Cleveland, Ohio, and the W. V. Panghorne Company of Philadelphia, Pa. had the subcontract for the electrical equipment.

The design of the bascule span was handled by the Strauss Engineering Corporation which is noted for many large bridge designs, among them being the Golden Gate Bridge in San Francisco. J. F. Kinter was in general charge of the construction of the bascule and the field operations were handled by H. F. Archinal and Frank Pierce.

The bridge was opened for traffic, which is limited to non-commercial vehicles, on May 6, 1932. A traffic count was taken on May 30 and it showed that in a period of 24 hours 26,460 cars crossed over the bridge.